Joint Fire Sciences Program Project # 08 – 1 – 6 -09

Validation of Smoke Transport Models with Airborne and Lidar Experiments

Fiscal Year 2010 Progress Report

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The project "Validation of Smoke Transport Models with Airborne and Lidar Experiments" is being conducted to address JFSP AFP-2008-1, Task 6 , 'Smoke and Emission Models Evaluation'. This report details the progress made towards achieving the project's primary deliverables during fiscal year 2010. This progress report is divided into four sections. Section 1 summarizes the objectives of this project and the manner in which accomplishing these objectives addresses JFSP AFP-2008-1, Task 6. Section 2 of this report provides background material on smoke dispersion and air quality forecasting systems. The goal of the Section 2 is to illustrate how the accomplished tasks contribute towards the project objective of providing smoke dispersion and fire environment datasets to validate smoke dispersion and air quality. A detailed report on the project's progress and achievements in provided in Section 3. The final section provides a list of accompany documents (deliverables) and a bibliography of publications and presentations delivered by this project.

1. Introduction

Wildland fire is a significant source of fine particulate matter ($PM_{2.5}$, particles with a diameter less than 2.5 μm) and nitrogen oxides and volatile organic compounds that can contribute to ozone (O_3) production and secondary organic aerosol formation. The Regional Haze Rule, recently revised National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ (the 24-hr ambient standard was reduced from 65 to 35 μg m^{-3}), and the proposed tightening of O_3 standards will increase the pressure on land management agencies to address the air quality impact from wildfire, wildland fire use, and prescribed burning. Land management agencies need rigorously tested, accurate models to quantify the contribution of fire emissions to air pollution (e.g. $PM_{2.5}$ and O_3) and visibility impairment. Accurately describing and predicting the dynamics of smoke plumes and subsequent smoke transport is a major uncertainty in determining the impact of fire emissions on air quality. While many smoke plume models exist, few smoke plume observational datasets are available to properly validate these models and quantitatively assess their uncertainties, biases, and application limits.

This project, which addresses JFSP AFP-2008-1, Task 6, 'Smoke and Emissions Models Evaluation', is measuring key variables with the spatial and temporal resolution required to validate plume rise models and high-resolution smoke dispersion models. A ground based, mobile LIDAR (**Li**ght **D**etection **A**nd **R**anging) instrument is deployed along with an airborne instrumentation package to acquire measurements of smoke plume dynamics, smoke aerosol distribution, chemical composition, and meteorological conditions in, and around, the plumes of active wildland fire events in the northwestern United States. The LIDAR measures plume rise height, dynamics, dispersion, and aerosol optical properties. The airborne instrument package, deployed on a Cessna aircraft, measures the 3-D distribution of aerosol mass density and major trace gas (CO, CO_2, and CH_4) concentrations. Multiple wildland fires will be investigated over 2 years, allowing the research team to measure plume rise and smoke transport over a wide range of meteorological, fire activity, fuel, and terrain conditions.

2. Background

The fundamental purpose of our research project is to acquire the data necessary for the evaluation of smoke dispersion and air quality forecasting systems. A diagram of a generic smoke dispersion / air quality forecasting system is provided in Figure 1. The datasets produced in this project will support model evaluation studies that provide a quantitative assessment of the uncertainties, biases, and application limits of the models examined. This project is obtaining **model validation data** by measuring prognostic variables of plume rise, smoke transport, and smoke chemistry models with the spatial and temporal resolution required to quantitatively validate a wide range of models. The subcomponent models, such as plume rise and fire effects models, rely on a variety of **fire environment data** as input including ambient meteorological conditions, fuel type, fuel loading, and fuel condition. In addition to measuring the 3-D distribution of model prognostic variables in the vicinity of active fire events, the project will also create a database of fire event variables which are the critical input for the subcomponent models of smoke dispersion and air quality forecasting systems.

2.1 Fire Environment Data

2.1.1 Fire Growth

Fire growth is determined by mapping the area impacted by a fire event over time. Mapping of fire progression provides the spatial information on the area impacted by fire and enables an estimate of the burned area and fuels involved. Fire growth may be determined from a combinations of incident perimeters and satellite observations (e.g. MODIS and Landsat).

2.1.2 Fuel Loading

Fuel loading – in simplest terms, the mass of fuel per a unit area – provides input needed to estimate fire behavior and fire effects. The complexity of a fuel loading map constructed for a specific fire event may be as minimal as the mass of above ground carbon per unit area or it may provide a detailed estimate of fuel loading according to components (canopy, down dead wood, litter, live, duff, etc.) and size classes. Fuel loadings are estimated by combining a fire area map with a fuel or vegetation type map and a fuel loading model. A fuel loading model is a representation of a fuel complex that provides fuel descriptors required as input for fire effects models. The complexity of a fuel loading map is determined by the requirements of the fire effects models employed for a particular application. The simulation of smoke impacts requires temporal and spatial estimates for a range of fire effects – fuel consumption, fire phase (flaming, smoldering), heat release, and emissions.

2.1.3 Fuel Consumption

Fuel consumption is typically estimated using models such as FOFEM, CONSUME, and FEPS. For input, fuel consumption models generally require fuel loading by fuel type and size class and information on fuel moisture. Meteorology, terrain (slope, aspect) and canopy cover all play a role in determining fuel moisture. Some fuel consumption models, such FOFEM and CONSUME, simulate the amount of fuel consumed during each phase fire (flaming, smoldering). Fuel consumption models may also provide an estimate of heat released by fire.

2.1.4 Emissions

Wildland fires emit a wide range of pollutants that degrade air quality. The composition and intensity of emissions depends on the type and amount of fuel burned and the fire phase – smoldering or flaming combustion. Emission intensities for a species X are estimated using emission factors which prescribe the mass of X emitted per unit mass of vegetation consumed by fire. For a specific species X the emission factor depends on the vegetation or fuel type and the fire phase.

2.1.5 Fuel Condition and Meteorology

Fuel condition refers to the relative flammability of fuel as determined by the fuel type and environmental conditions. A key component of fuel condition is fuel moisture which is typically evaluated according to National Fire Danger Rating System (NFDRS) fuel classes. Fuel moistures by NFDRS fuel class are critical input for models that predict fuel consumption, fire spread , and fire behavior. Limited measurements of fuel moisture may be obtained from the Fire Behavior Analysts (FBAN) assigned fire incidents, and a small share of the meteorological observing stations which are part of the Real-time Observing Monitor and Analysis Network (ROMAN) report 10-hour fuel moisture. Due to the general lack of in-situ fuel moisture measurements, meteorological observations are often used to estimate fuel moistures using the NFDRS methodology. In addition to fuel moisture, wind speed and direction is another input needed for fire spread and fire behavior models (and some consumption models). The various plume rise models require an assortment of meteorological observations as input. Depending on the plume model employed the necessary meteorological data may include wind speed, pressure (P), air temperature (T), virtual temperature (Tv), the vertical lapse rates of T and Tv, and solar radiation or cloud cover. Some models, such as PLUMP and DAYSMOKE, require a vertical profile T, P, and dewpoint temperature (Td). DAYSMOKE also needs the vertical profile of wind speed and direction.

2.2 Model Validation Data

Smoke dispersion and atmospheric chemistry forecasting systems predict smoke impacts on air quality by simulating the temporal evolution of the 3-D concentration fields of smoke aerosol and other pollutants (e.g. CO and O_3). The LIDAR and airborne observations collected in this study will be used to validate the pollutant concentration fields simulated by these forecasting systems. This study will also provide observations of plume rise height for validation of the various plume rise models which are key subcomponents of smoke dispersion and air quality forecasting systems. These sub-grid scale plume rise models are typically embedded in the columns of host 3-D smoke dispersion and atmospheric chemistry models and are used to prescribe the vertical distribution of fire emissions. Predictions of three plume rise models and a smoke dispersion model are provided in Figures 2 & 3 to illustrate how the observations acquired in this study may be used to evaluate the performance of these models.

2.2.1 Plume Rise

The ability of plume rise models to accurately capture the plume behavior of wildland fires is highly uncertain. The plume rise predicted by these models can be quite different for a given fire. Figure 2 shows hourly plume rise heights (ΔH) predicted by 3 different plume models for the Bugaboo Scrub Fire in southern Georgia on May 8, 2007. The importance of plume rise models in assessing the air quality impacts of fire emissions is demonstrated in Figure 3. Plume rise predictions from Figure 2 were used to vertically distribute fire emissions in two WRF-Chem simulations. Figure 3 shows the predicted O_3 surface concentration field at 1500 EST on May 8, 2007. Ozone is a secondary pollutant formed through photochemical reactions of volatile organic compounds and nitrogen oxides (both are emitted by wildland fire) and thus, the peak O_3 is downwind of the fire. The two plume rise models produce very different predictions of the fire's air quality impact. The predicted peak O_3 and high O_3 area (> 80 ppb) differs by about 100%, due solely to the different plume rise models.

LIDAR is a potent tool for measuring the physical dimensions of smoke plumes, especially plume rise height, ΔH. Using the Atmospheric Heterogeneity Height Indicator (AHHI) algorithm (see FY09 progress report) the maximum plume rise can be derived from a large volume of LIDAR data to provide an accurate time series of ΔH observations. Vertical profiles obtained with the airborne instrument package also provide a precise measurement of ΔH.

2.2.2 Smoke Dispersion

An example of an aerosol concentration field simulated with WRF-Chem, an air quality forecasting model, is given in Figure 4. Mobile LIDAR is an efficient tool for measuring the rise height and physical dimensions of smoke plumes. However, LIDAR alone cannot provide the observations needed to evaluate smoke dispersion models due to two key limitations: limited range (maximum of $\approx$ 12 km) and an inability to measure aerosol concentration. When suitable instrumentation is deployed on an aircraft, appropriate sampling maneuvers, such as vertical profiles and horizontal transects downwind of an active fire, can provide measurements for validating simulations results like that depicted in Figure 4.

2.2.3 Emissions

Aircraft based measurements of aerosol, CO_2, CO, and CH_4 concentrations in fresh smoke can be used to validate the model emissions of these species. Furthermore, enhancements of CO_2 and CO in smoke relative to the background air can be used to derive the modified combustion efficiency

(MCE) of the fire. The emission intensities of many reactive compounds released by fires are proportional to the fire's MCE. Thus, CO_2 and CO measurements provide an avenue to estimate the emissions of a wide range of compounds (based on their MCE dependence). Further, the measurements of the MCE for multiple wildfire events in the western U.S. that are being obtained in this project address a crucial knowledge gap. While laboratory studies and field studies of *prescribed fires* have established X – MCE relationships (where X is a reactive compounds released by fires) , there are few measurements of MCE for wildfire events in the U.S. By providing measurements of MCE for wildfire events, this project will improve the emission estimates used as input for smoke dispersion and air quality forecasting models.

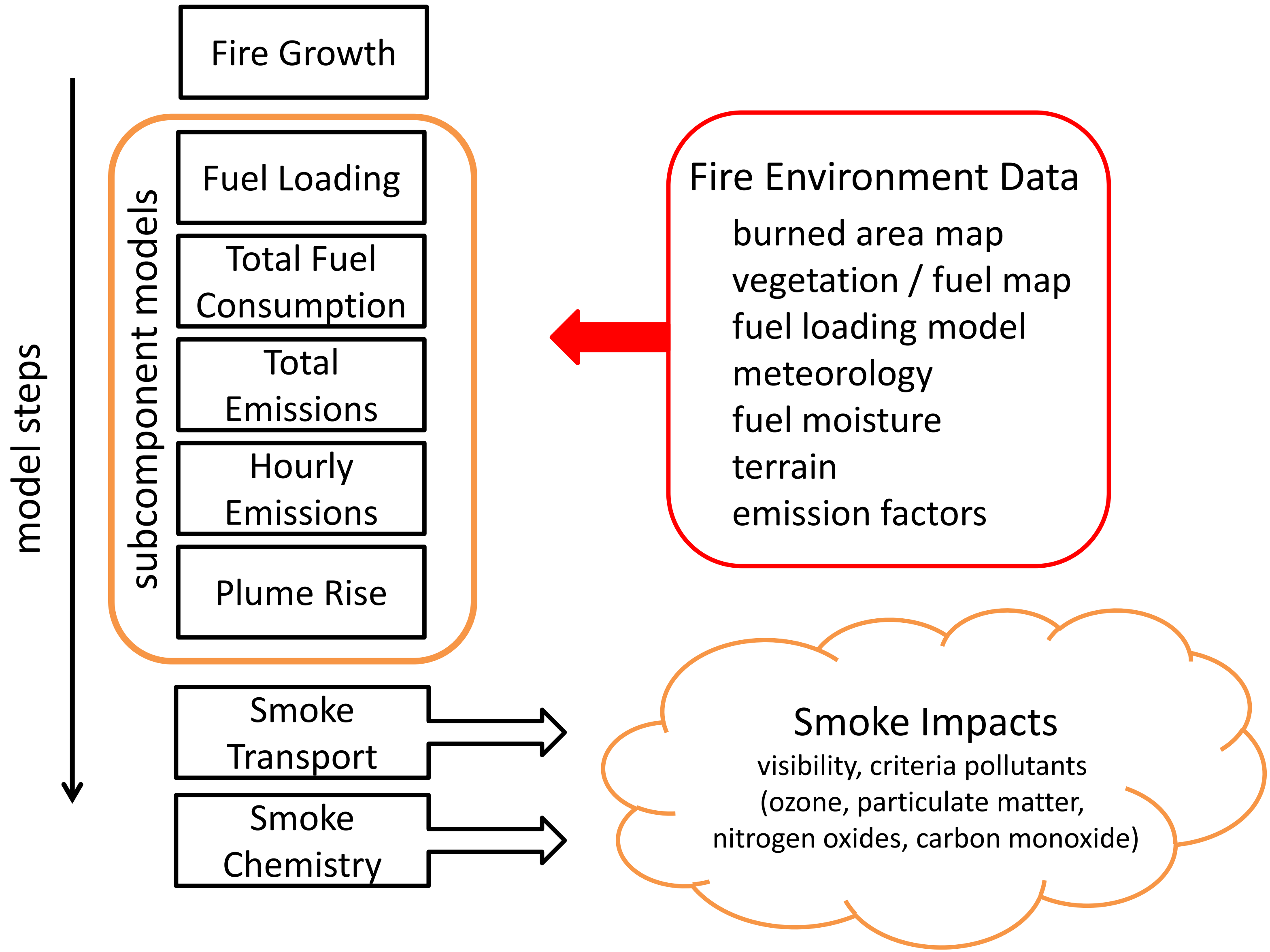


Figure 1. Generic smoke dispersion – air quality forecasting system

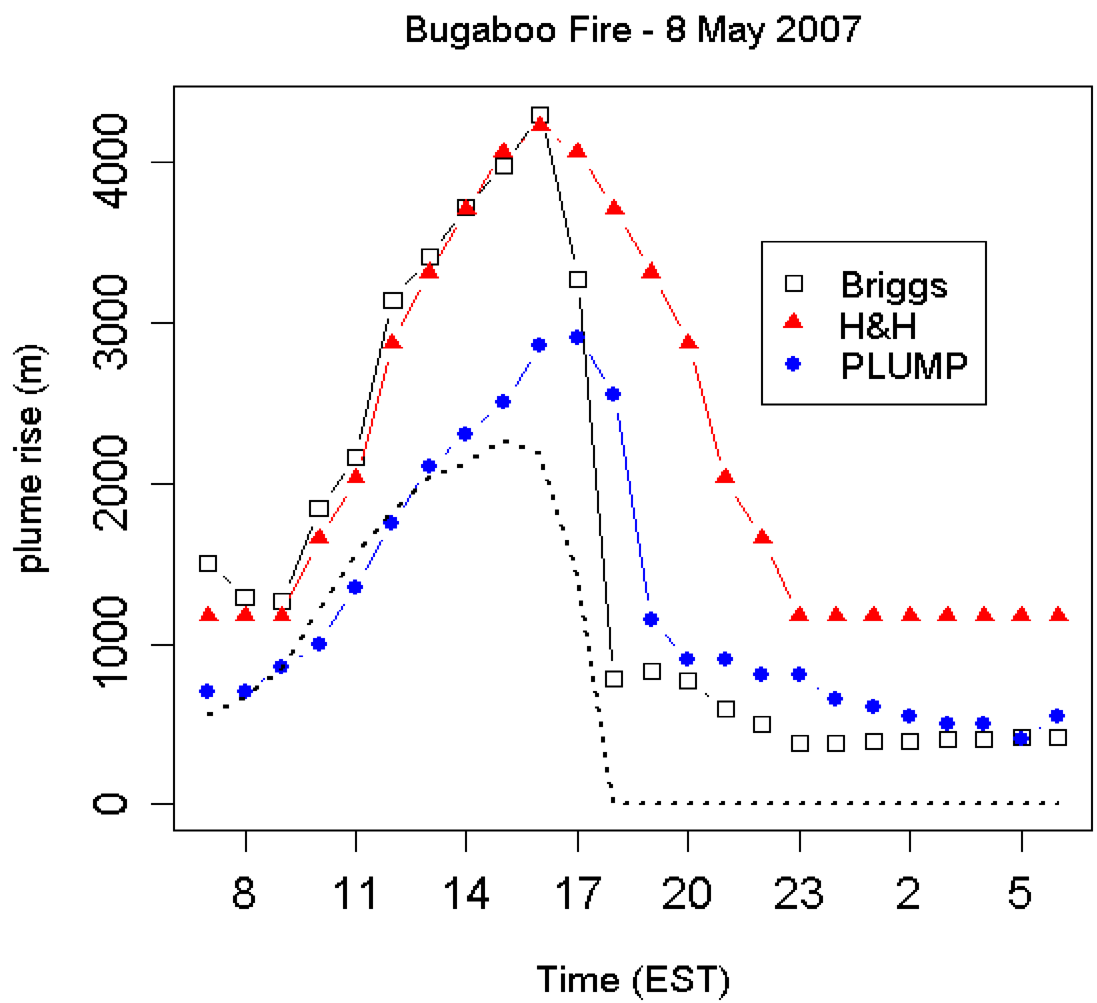


Figure 2. Predicted plume rise height (ΔH) for the Bugaboo Scrub Fire in southern Georgia on May 8, 2007. Dashed black line is the WRF-SD predicted planetary boundary layer height. Briggs = Briggs equations, H&H = Harrison and Hardy empirical model.

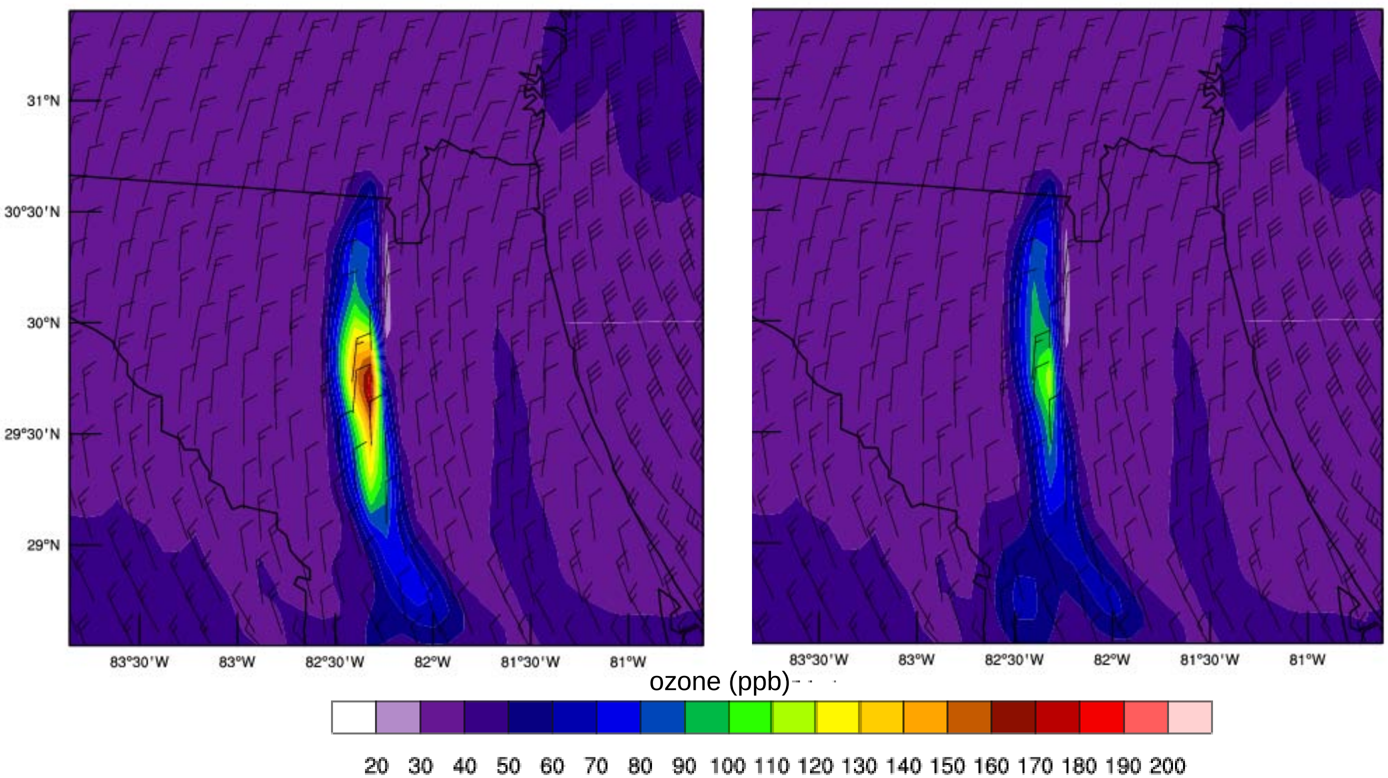
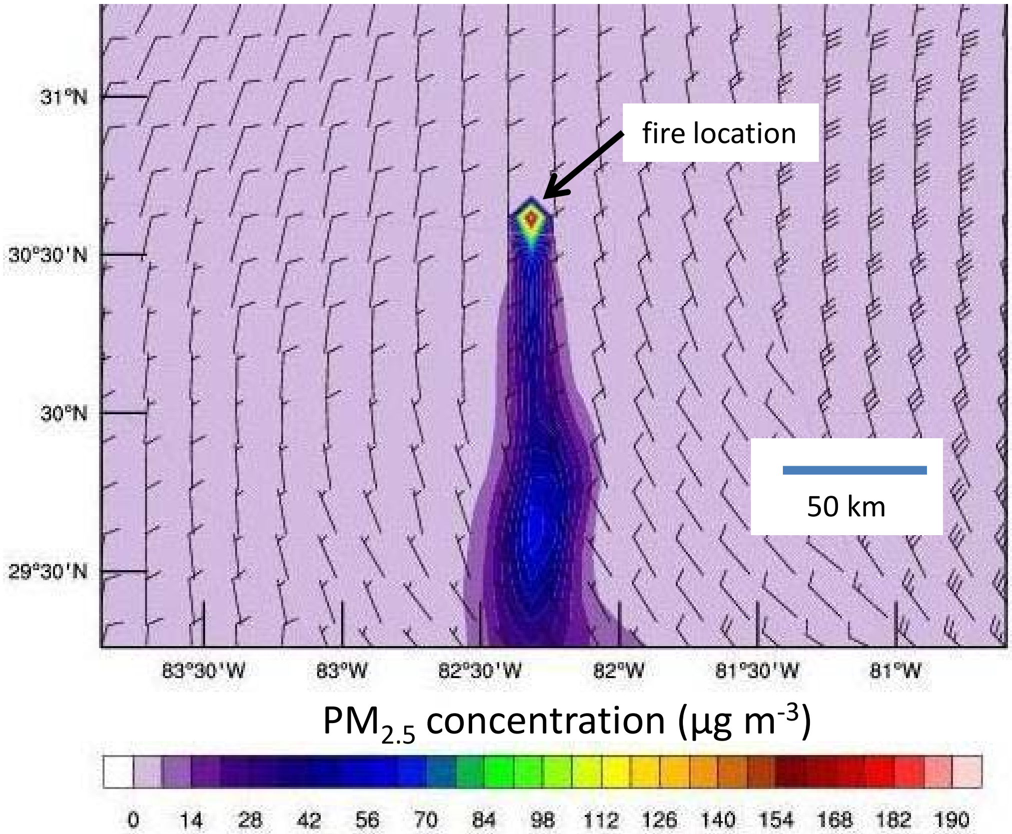


Figure 3. WRF-SD simulated O_3 plume from the Bugaboo Scrub Fire on May 8, 2007. The plume rise heights used in the simulations were predicted with PLUMP (left panel) and Briggs equations (right panel). Winds units are knots (1 full barb = 10 knots) and ozone units are parts per billion.

Figure 4. Simulated aerosol concentration field for the Bugaboo Scrub Fire on May 8, 2007. Simulation by WRF-Chem air quality model.



3. Accomplishments

The project duration is 3 years, with a start date of June 1, 2008 and a completion date of May 31, 2011. The primary deliverables of this project are:

- A comprehensive database of field observations and fire environment data for multiple fire events in the western U.S. for distribution to Smoke Emissions Model Intercomparison Project (SEMIP, JFSP project #08-1-6-10)
- Project final report describing: 1) the aircraft and lidar instrumentation systems, calibration and data quality control, 2) flight patterns and data processing, 3) the wildland fire events studied, and 4) field measurement results and data analysis
- Manuscripts for publication in peer reviewed journals

The comprehensive database is to be provided to SEMIP **by May 31, 2011**. The due date of the project final report is **May 31, 2011**. The final comprehensive database will be comprised of **model validation data** (plume rise, smoke dispersion, and emissions measurements acquired with mobile LIDAR and airborne instruments) and **fire environment data** for multiple fire events in the northwestern U.S. Because the project requires an aircraft (with the instrumentation installed and flight tested) and pilot for short notice deployment, it was necessary to select a fixed window for the field work and secure exclusive use of an aircraft and pilot for this entire period. Historically August is the month of peak fire activity in the northwest U.S. and we selected this month as our deployment window. In both 2009 and 2010 we secured an aircraft and pilot for exclusive use during the month of August. In 2009 and 2010, wildfire activity in the project's target region (northwestern U.S.) during the month of August was well below that of the preceding decade (see Figure 5). The August burned area in both 2009 and 2010 was only 20% of the 1999 – 2008 median burned area (102,000 and 114,000 acres, respectively, compared to 555,000 acres) . This tremendous lack of fire activity for consecutive years has severely limited the opportunities available for the project to make progress on accomplishing the primary deliverables. Despite the challenging environment the project has made progress towards achieving the final deliverables. The project's progress during fiscal year 2010 is reported here according to key accomplishments:

Fiscal Year 2010:

- Development of an updated Project Aviation Safety Plan
- Publication of three papers presenting methods and results of project
- Assembly of a model validation dataset for 3 fire events for which data were collected in 2009
- Acquisition of fire environment data for the 3 fire events studied in 2009
- Deployment of LIDAR and/or airborne assets to 7 wildland fire events during the summer of 2010

3.1 Development of Project Safety Aviation Plan

The use of aviation for research is a potentially high-risk activity. This is especially true when the research involves an active fire event with fire aviation traffic. Risk management is used to mitigate the likelihood and/or severity of hazards and thus reduce the risks associated with an activity. Risk management for this project began with the development of the project Research Operations Plan for the aviation portion of the field deployment. During the early summer of 2009, the project PI collaborated with the USFS Region 1 Supervisory Pilot (Michael Peitz) and then Northern Region Aviation Safety Manager (Eddie Morris) to develop a Project Aviation Safety Plan (PASP) based on the Research Operations Plan. The PASP was reviewed by the Region Aviation Officers for the Pacific Northwest, Rocky Mountain, Intermountain, and Northern Regions. The 2009 PASP served as a draft for the project's 2010 PASP. The PSAP was updated with several modifications for 2010. The 2010 PASP was reviewed and approved by the Region Aviation Officers for the Pacific Northwest, Rocky Mountain, Intermountain, and Northern Regions. The PSAP developed for this project has served as a template for two additional Forest Service research projects employing airborne assets. The 2010 PASP has been included with this progress report (see Section 4).

3.2 Publications

One of the primary deliverables of this project is the presentation and distribution of research results and science findings in peer-reviewed journals and publications. In fiscal year 2010, the project delivered 3 publications. The references for the 3 publications are included the bibliography of this report (Section 4). Electronic copies of the publications have also been provided as project deliverables to the JFSP. A brief description of the papers is provided next.

During the summer of 2009 the project successfully deployed to the Kootenai Creek Fire and this event served as the project's initial case study. The Kootenai Creek Fire case study was published in the Proceedings of the 25th International Laser Radar Conference. This paper demonstrates the utility of combining ground-based LIDAR with airborne measurements to acquire the data necessary for the evaluation of plume rise and smoke dispersion models. The paper "Scanning LIDAR Using Alternative Functions for Establishing the Atmospheric Heterogeneity Locations" reports on the development of LIDAR data-processing techniques that allow for the determination of the upper and lower boundaries of a smoke plume or smoke layering in the vicinity of wildfires. The third publication of FY10, "Essentials of Multiangle Data-Processing Methodology for Smoke Polluted Atmospheres", reports on the two different LIDAR data acquisition and analysis techniques employed in this project. One technique, Program 1, is used to study the dynamics of smoke layering and plumes, and to investigate the changes of their heights in time space. Program 1 provides measurements of the upper and lower boundaries of smoke plumes or smoke layers and the fluctuations of these over time. These measurements can be used to validate smoke injection heights and smoke vertical profiles predicted by plume rise models. The second technique is employed to extract optical properties of the smoke polluted atmosphere, such as smoke particle optical depth and the extinction coefficient profile.

3.3 Summer 2010 Field Deployment

3.3.1 Summary of 2010 Northwest fire season

The focus of the project is wildfire events in the northwestern U.S., in particular Montana, northern Idaho, Washington, and Oregon. This area corresponds to the regions organized as the Northern Rockies and Northwest Geographic Area Coordination Centers (GACC). The primary target of the project is large, long-duration events which exhibit active fire behavior over many days. Such events are favorable for successful field deployment. The aircraft research team may reach a fire event and begin science flights in less than 24 hours after a decision is made to deploy. However, the ground based LIDAR team typically requires more time for mobilization. The LIDAR team must complete several tasks before research may begin: travel to the incident, team check-in at the incident, coordination with the Incident Management Team, and identification of suitable location for deployment of the LIDAR. Once a decision has been made to deploy to an event, the LIDAR team may require 2 – 3 days before it can be positioned to acquire smoke plume observations. For this reason, large, long-duration events which exhibit active fire behavior over many days are most suitable for study in this project.

The study research plan is designed for deployment during August, the month of peak fire activity in this region, and the period when large, long-duration fire events are most frequent and most active. The 2010 northwestern U.S. fire season was extremely inactive and offered few promising fire events for study by the project. The fire season was dramatically different from the typical pattern of the previous decade (see Figure 5). In the decade preceding 2009, the median August burned area in the Northern Rockies and Northwest was 555,000 acres. In 2010, fire occurrence and acres burned was well below that observed in 8 of the 10 years between 1999 – 2008. In 2010, only 110,000 acres were burned by wildfire in the Northern Rockies and Northwest in the month of August. This was the second consecutive year of unusually low fire activity in this region. The lack of suitable fire events in the primary study region limited the success of the 2010 field deployment, much as it did in the preceding year.

3.3.2 Deployments

The lack of sustained, large fire events significantly limited deployment opportunities in August, 2010. However, the project did manage to deploy the LIDAR and/or airborne research teams to 7 different fire events (Table 1). Unfortunately, due to the short duration of most of the fire events, we were able to co-deploy the LIDAR and aircraft on only two of the fire events. Several of the fire Many of the fire The success of the deployments, as gauged by the acquisition of observations for the validation model simulations (plume rise, smoke dispersion, emissions) was highly variable (Table 1). The locations of wildfire events studied in 2009 and 2010 are mapped in Figure 5. Processing and initial analysis of the LIDAR and airborne data obtained during the field deployments is currently underway. The organization of fire environment data for each fire event is ongoing. A preliminary dataset of smoke dispersion measurements has been assembled for the Casner Fire and some of the results are presented in Section 3.3.3.

Table 2. Project Field Deployments

Fire Name	Location	Date(s)	Model Validation Data Acquired: LIDAR plume rise	Aircraft plume rise	Aircraft dispersion	Emission
2010 Wildfire Field Deployments						
Rooster Rock Fire	Deschutes NF Sisters, OR (-121.584, 44.219)	Aug 4 - 6		**X**	**X**	**X**
Twitchell Canyon Fire	Fishlake NF Beaver, UT (-112.499, 38.425)	Aug 12,13,15-17	**X**	**X**	**X**	**X**
Hurd Fire	Boise NF Cascade, ID (-116.166, 44.606)	Aug 24		**X**	**X**	**X**
Banner Fire	Salmon – Challis NF Stanley, ID (-115.21, 44.38)	Aug 25		**X**	**X**	**X**
Casner Fire	Boise NF Lowman, ID (-115.508, 44.287)	Aug 27		**X**	**X**	**X**
Alder Creek Fire	Lolo NF Stevensville, MT (-113.851, 46.438)	Aug 25, 26	**X**			
Downing Mountain Fire	Bitterroot NF Hamilton, MT (-114.25, 46.242)	Aug 27, 28	**X**	**X**		
2009 Wildfire Field Deployments						
Kootenai Creek Fire	Bitterroot NF Stevensville, MT (-114.24, 46.55)	Jul 21,22 Aug 4, 26-28	**X**	**X**	**X**	**X**
Mill Flat Fire	Dixie NF New Harmony, UT (-113.38, 37.46)	Aug 21,22		**X**	**X**	**X**
Sand Basin Fire	Beaverhead – Deerlodge NF Philipsburg, MT (-113.72, 46.187)	Aug 27		**X**	**X**	**X**

3.3.3 Casner Fire – Preliminary Results

The project deployed to the Casner Fire on August 27, 2010. The Casner Fire, located 15 miles northeast of Lowman, ID, was one of roughly 20 new starts ignited by lightening on the Boise National Forest on August 26. Fortunately, the aircraft research crew had positioned in McCall, ID, near the relatively inactive Hurd Fire, earlier in the week in anticipation of the hazardous fire conditions that were forecast for the region. Comprehensive measurements of plume rise, smoke dispersion, and emissions were obtained with the airborne instruments (see Table 2). The fire location, aircraft flight path, and measured aerosol concentration during constant elevation transects are shown in Figure 6. The horizontal smoke dispersion measurements were using transects at a constant elevation of ~ 1300 m above ground level. The aircraft flight path included three 30 km segments, oriented perpendicular to the transport winds (i.e. the direction of the plume flow) and located at distances of 15, 30 , and 40 km downwind of the active fire. Two additional transects were conducted parallel with the smoke transport, these transects extend as far as 50 km downwind. The aircraft sampling also included a vertical profiles taken ≈ 10, 15, and 50 km downwind of the active fire. Figures 7 and 8 present the aerosol concentrations measured during the airborne transects and a vertical profile. The observations in Figure 8 may be used to validate plume rise heights predicted by models such as Daymsoke, PLUMP, and the Briggs equations. The aerosol concentrations (Figures 6-8) may be used to validate the concentration fields simulated by high-resolution smoke dispersion models, such as the simulated $PM_{2.5}$ concentration field at depicted in Figure 4.

3.4 Fire Environment Database

The objective of this project is to obtain model validation data by measuring prognostic variables of plume rise, smoke transport, and smoke chemistry models (hereafter *smoke and emission models*) with the spatial and temporal resolution required to quantitatively validate a wide range of models. The smoke and emission models to be evaluated with the smoke emission and dispersion measurements collected in this project rely on variety of fire environment data as input, either directly or through subcomponent models (e.g. the CONSUME fuel consumption model). The fire environment data is needed to progress through the model steps depicted in Figure 1 and produce a simulation of plume rise, smoke dispersion or air quality that can be evaluated with the model validation data being collected in this project. Therefore, in addition to smoke emission and dispersion measurements, the project is also gathering fire environment data.

The required fire environment data (see Section 2) varies considerably in complexity and availability. *Fire Growth*, the mapping of the burned area over time, may easily be mapped from a time-series fire incident perimeter polygons. Fire growth maps derived from incident perimeters may be refined with remote sensing products such as Burned Area Reflectance Classification (BARC) maps, Rapid Assessment of Vegetation Condition after Wildfire (RAVG) maps, or Burn Severity maps to account for unburned regions within the perimeters. Burn Severity, BARC, and

RAVG products are produced by the USDAS Forest Service Remote Sending Applications Center (RSAC) and are available for many fire events. Incident fire perimeters are generally available through GEOMAC or the NIFC ftp site. However, the holdings of these sources may be incomplete.

In contrast, *Fuel Consumption* is frequently modeled using an assortment of input data including fuel loading and fuel moisture. Fuel moisture in turn relies on the mapped fuel type, and environmental (slope and aspect) and meteorological conditions. High-resolution maps of vegetation, fuel type, aspect, slope, and other landscape properties are readily obtained through LANDFIRE (http://www.landfire.gov/) and meteorological observations are available through ROMAN or the Western Regional Climate Center archive.

Some of the fire environment data and observations being collected in this project can only be obtained through interaction with personnel involved with a particular fire incident. Examples of such data include in-situ measurements of fuel moisture, maps delineating the location and timing of burnout operations, and fire perimeters not uploaded to the NIFC ftp site.

Therefore, in addition to smoke emission and dispersion measurements, the project is also gathering fire environment data. The project is assembling fire environment data for each fire event for which smoke emission and dispersion measurements were obtained. The fire environment data being assembled is categorized in Table2. **The project has collected the available fire environment data for the all of the fire events studied in 2009** (see Table 1).

Table 2. Fire Environment Data

Category	Purpose
• Incident fire perimeters • MODIS burn scar and active fire detections • Landsat images • BARC maps • RVAG maps	Mapping of burned area mapping and fire growth Post-fire assessment of fire severity and fuel consumption LANDSAT images can be used to create BARC and RAVG maps for incidents RSAC has not processed
Landfire data layers • Existing vegetation type • Fuel loading models • FCCS • FB13 and FB40	Mapping of fuel / vegetation type and fuel loading Provides input for fire effects and fire behavior models
Landfire data Layers • aspect • slope • elevation	Estimation and mapping of fuel moistures Provides input for fire effects and fire behavior models
Meteorological data: • RAWS stations • Incident meteorological /fuel observations	Estimation of fuel moistures Provides input for fire effects and fire behavior models

4. Appendix

Bibliography and Accompanying Documents

The following documents and publications have been uploaded as project deliverables to the Joint Fire Sciences Program database for this project (08-1-6-09):

1. V. Kovalev, A. Petkov, C. Wold, and W. M. Hao, "Determination of the smoke-plume heights with scanning lidar using alternative functions for establishing the atmospheric heterogeneity locations," in *Proceedings of the 25th International Laser Radar Conference.* (5–9 July 2010, St.-Petersburg, Russia), Tomsk, Publishing House of IAO SB RAS, 2010, pp. 71-74.
2. Shawn Urbanski, Vladimir Kovalev, Wei Min Hao, Cyle Wold, and Alex Petkov, "LIDAR and airborne investigation of smoke plume characteristics: Kootenai Creek Fire case study," in *Proceedings of the 25th International Laser Radar Conference.* (5–9 July 2010, St.-Petersburg, Russia), Tomsk, Publishing House of IAO SB RAS, 2010, pp. 1051-1054.
3. V. A. Kovalev, A. Petkov, C. Wold, S. Urbanski, and W. M. Hao, "Essentials of multiangle data-processing methodology for smoke polluted atmospheres," Romanian Journal of Physics (in press).

The following document has been included as an appendix to this report:

2010 Project Aviation Safety Plan

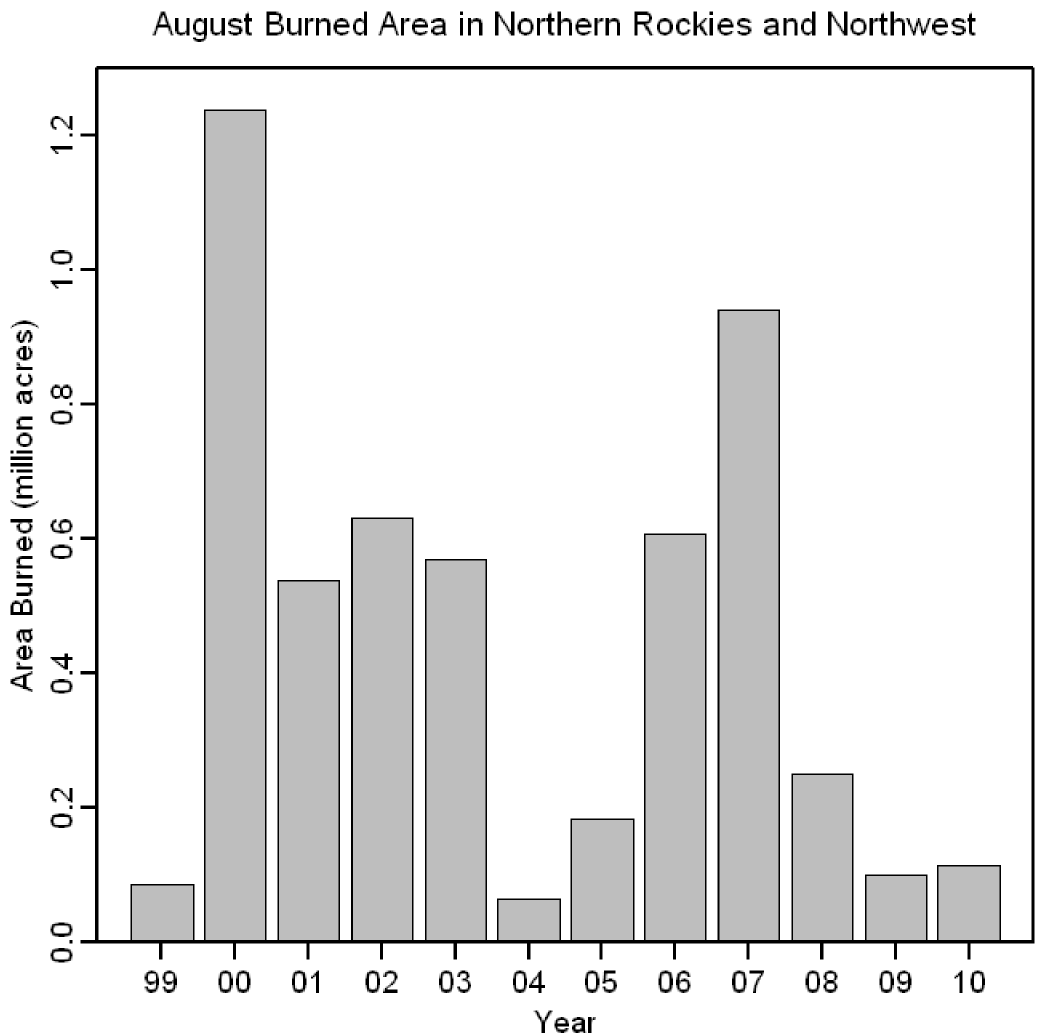


Figure 5. August wildfire burned area in the northwestern U.S. (Northern Rockies and Northwest GACCs) 1999 – 2010. The median burned area for 1999 - 2008 was 555,000 acres. The burned area was 102,00 acres in 2009 and 114,000 acres in 2010. Data from National Interagency Fire Center, Incident Management Situation Report Archive (http://www.predictiveservices.nifc.gov/intelligence/archive.htm).

Casner Fire - August 27, 2010
Boise National Forest

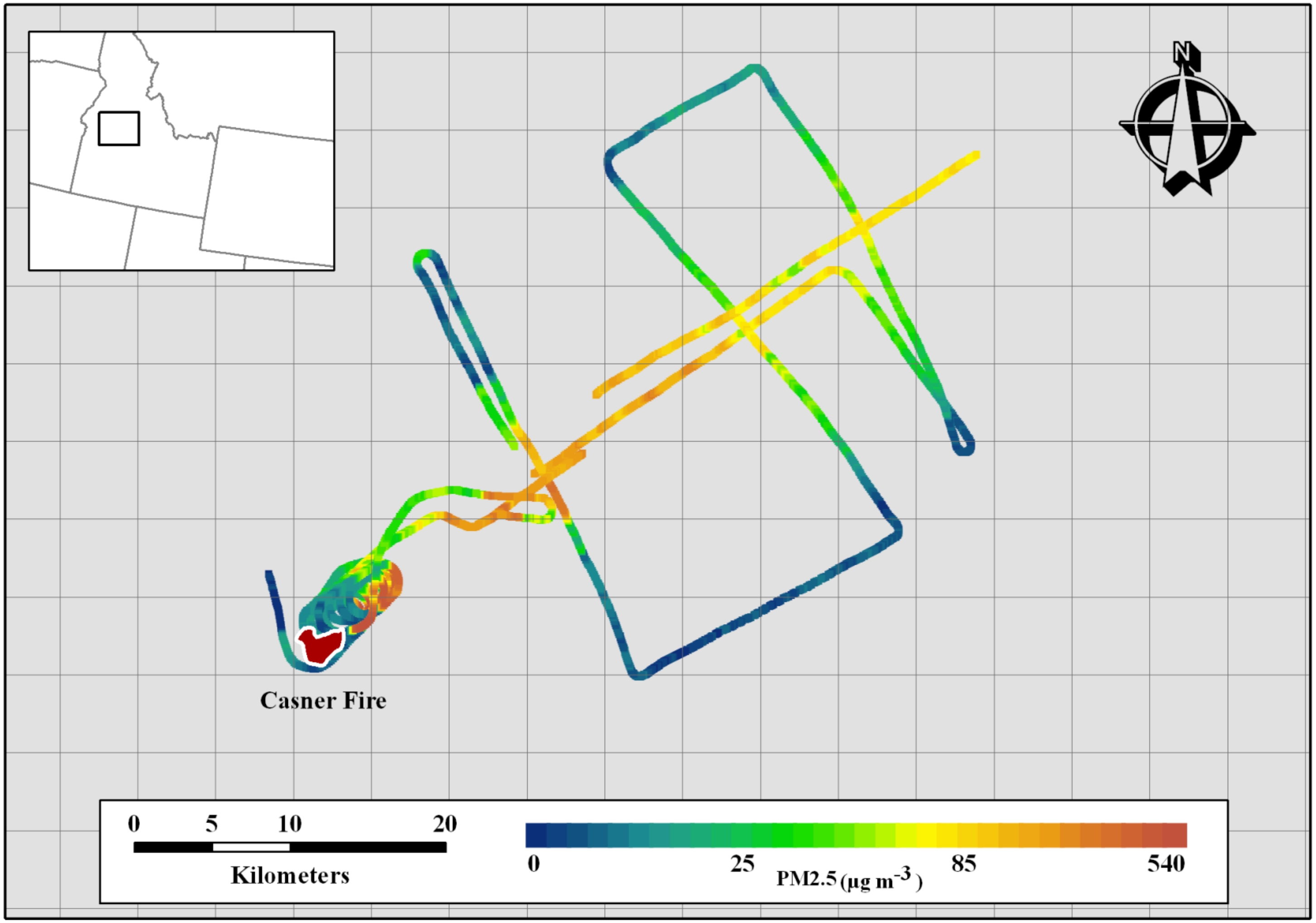


Figure 6. Casner Fire field deployment of August 27, 2010. Flight path with measured aerosol mass concentration and fire perimeter. All data shown was acquired at an elevation of ~ 1300 m above ground level.

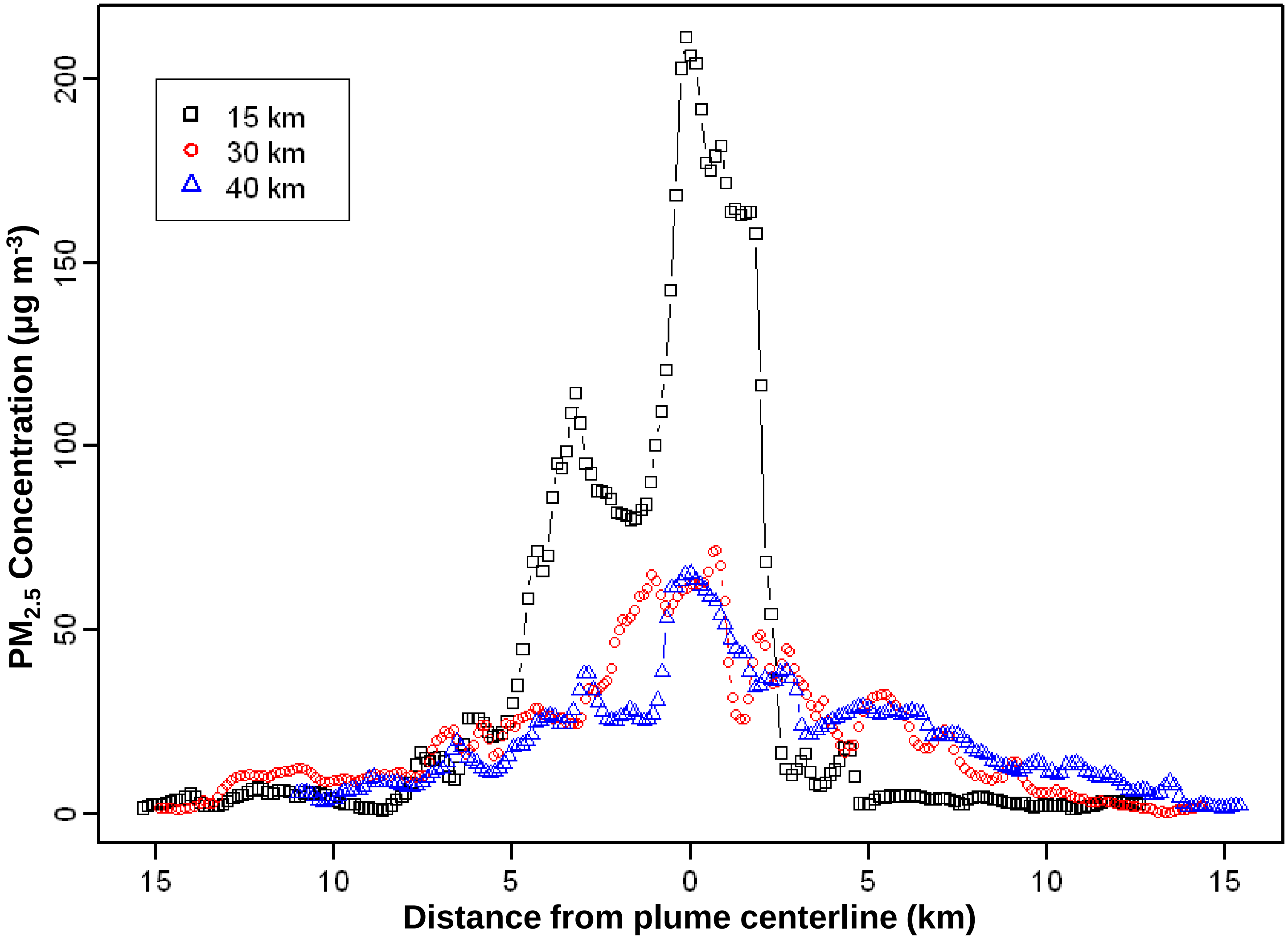


Figure 7. Airborne measurements of aerosol concentration downwind of the Casner Fire on August 27, 2010. The transects were taken at distances of 15, 30, and 40 km from the active fire. All transects were obtained at a constant elevation of ~ 1300m agl. Flight path with measured aerosol mass concentration and fire perimeter. All data shown was acquired at an elevation of ~ 1300 m above ground level.

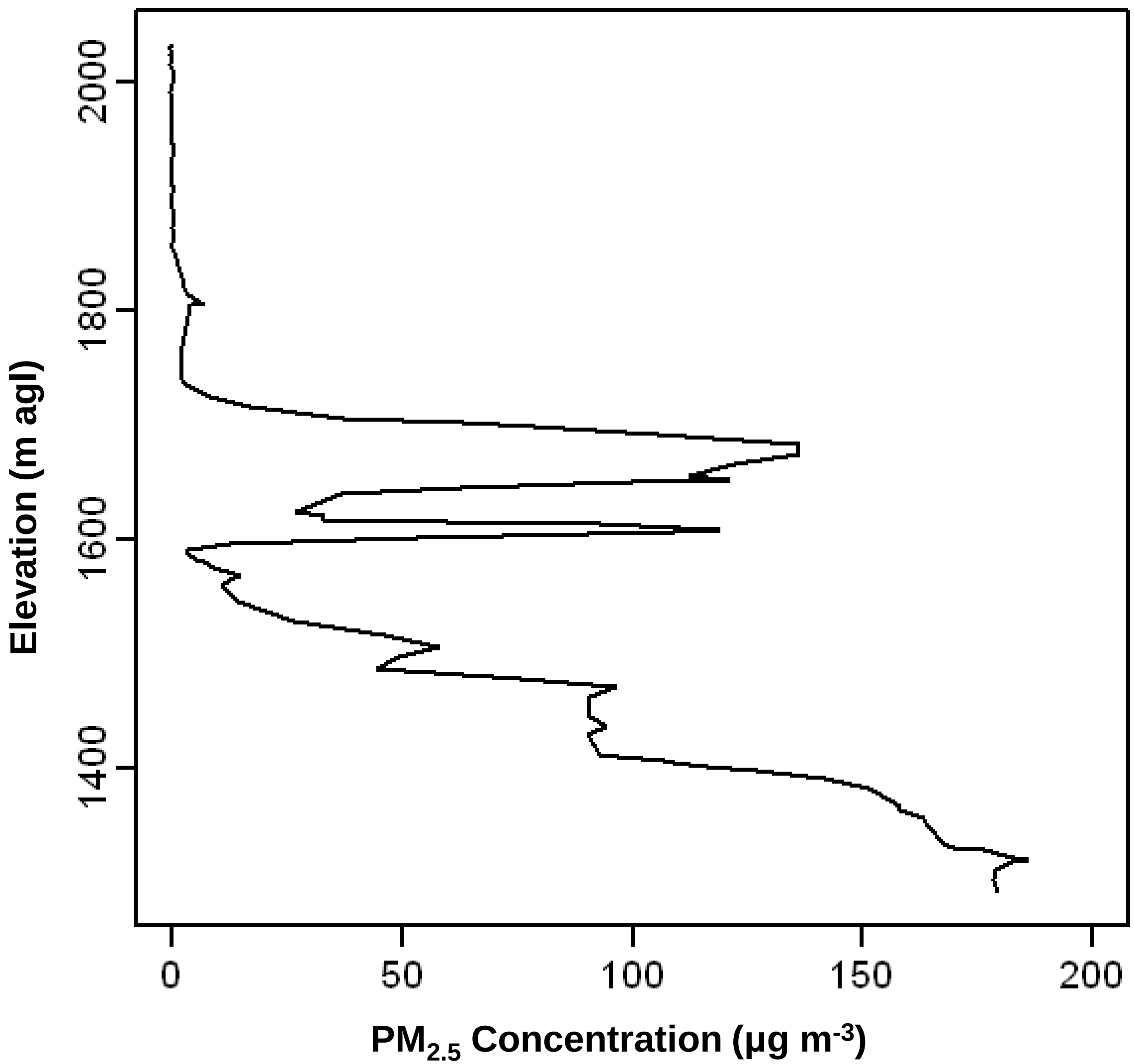


Figure 8. Vertical profile of aerosol concentration 15 km downwind from the Casner Fire.

AIRBORNE EXPERIMENTS FOR THE VALIDATION OF SMOKE TRANSPORT MODELS

This Research Project is a
Joint Fire Science Program
Rapid Response Study

PROJECT AVIATION SAFETY PLAN--2010

Prepared by: [signature]
Michael J. Peitz
Northern Region Supervisory Pilot
Date: 7/30/10

Reviewed by: /s/ Bob Gilman
Bob Gilman
Northern Rockies Operations Officer
Date: 7/29/2010

Reviewed by: /s/ Gary Sterling
Gary Sterling
PNW Region Aviation Safety Mgr
Date: 7/30/2010

Reviewed by: /s/ Jonathon M. Rollens
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PNW Region Aviaiton Officer
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Rocky Mountain Region Aviation Officer
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Date: 7/30/2010

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Northern Region Aviation Officer
Date: 7/30/2010

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Colin Hardy
Fire, Fuel, and Smoke Science Program Manager
Date: 8/2/2010

1. Supervision.

The Project Manager is Shawn Urbanski, Rocky Mountain Research Station. The Project Aviation Manager is Michael Peitz, R1 Supervisory Pilot. The Lead Scientist and Engineer have completed Fixed Wing Flight Manager training and are current.

2. Project Name and Objectives.

AIRBORNE EXPERIMENTS FOR THE VALIDATION OF SMOKE TRANSPORT MODELS -

The research team deploys an airborne instrument package to wildland fire incidents to measure the rise height, dispersion, aerosol density, and chemical composition of smoke plumes. The measurements provide data needed to quantify uncertainties, biases, and application limits of smoke dispersion and air quality models, thereby supporting and facilitating science application projects tasked with providing tools and guidance to fire managers, land use management agencies, and air quality regulators.

3. Justification.

The Team needs to mobilize to incidents in the western United States during the month of August, 2010 in order to observe multiple fire events and collect samples. The goal of the project is: **Evaluate plume rise and smoke dispersion models.** The mission will deploy the airborne smoke measurement instrument on the USFS Region 1 (R1) Cessna 206. The mission will require exclusive use of the aircraft throughout the month. No other practical means of acquiring this type of data over the large expanse of geographic area and limited timeframe has been identified.

4. Project Date(s).

The mission plans for approximately 15 to 20 flight days during the month of August, 2010.

5. Location.

Locations are dependent on wildland fire occurrence. Fire events will be targeted in the following western United States: Idaho, Utah, Montana, western Wyoming, Colorado, Oregon, and Washington. The preference is to base the mission out of Missoula; however, depending on the location of fire activity, it may be necessary to base to mission at additional, suitable, alternate locations at some point during the month.

6. Projected Cost of Aviation Resources.

This project will be charged to FRJF1F / 2216. The mission plans for up to 80 flight hours. At a use rate of $438.00 per hour (includes pilot labor), the projected total flight hour cost is $35,040.00. Lodging and M&IE for the pilot will vary based on location; however, utilizing the CONUS lodging and M&IE rate ($116.00), the pilot's projected per diem for up to 27 days is $3132.00. The projected total cost of the aircraft, associated labor of the pilot, and pilot per diem is $38,172.00.

7. Aircraft.

The mission will deploy the airborne smoke measurement instrument on the USFS Region One (R1) Cessna 206 (TU206F), N111Z.

8. Pilot(s).

The Primary Pilot will be Eldon Hatch.

9. Participants.

All three Research Team members have completed the requirements for general aviation training of aircrew members (A-101, A-105, A-106, A-108, and A-113) through the Interagency Aviation Training web-based training system and are current. All three Research Team members participated in this mission in 2009 and are familiar with the primary pilot, the specific airplane, and the interface between the smoke sampling instrument package and the airplane on which it is installed. The primary pilot also participated in this mission in 2009 and has an inherent understanding of the communication and coordination required to ensure its safe success.

10. Flight Following and Emergency Search-and-Rescue.

The Cessna 206 (TU206F) R1 Fleet Aircraft, N111Z, is equipped with an Automated Flight Following system (AFF). The primary means of flight following will be by AFF with radio flight following as a backup. The flight crew will follow the procedures outlined in the 2010 National Mobilization Guide Chapter 20 lines 4-45.

If Emergency Search-and-Rescue is required for the mission aircraft, it will be coordinated by local dispatch and/or local geographical coordination centers in accordance with associated standard operating procedures.

11. Aerial Hazard Analysis.

a. Prior to sampling in a new area, the pilot will request a briefing on aerial hazards and a copy of the Aerial Hazard Map for that area.

b. In confined areas (such as deep, narrow canyons), the pilot will conduct a high level recon followed by a lower level recon for aerial hazards prior to the beginning of sampling.

c. The pilot will accomplish necessary planning concerning temporary flight restrictions (TFRs) and coordination with the Federal Aviation Administration and military authorities (if appropriate) prior to project flights. De-confliction of any military training routes or military operations areas will be requested through local dispatch.

d. The aircraft will be flown along the edges of the plume to determine plume rise and to gather samples. The aircraft will not penetrate the smoke plume unless the plume is transparent enough to see through and maintain visual references necessary for safe flight. Any plumes that result from extreme fire behavior and that may contain burning embers and debris will be avoided.

12. Protective Clothing/Equipment.

Personal Protective Equipment shall consist of, as a minimum, Nomex (Aramid) or natural fiber materials (non-synthetic), shoes that fully cover the feet, and long pants that overlap the shoes when in the seated position. Long sleeve shirts are recommended.

13. Load Calculations and Weight-and-Balance.

Weight and Balance calculations will be determined by the pilot prior to each mission.

14. Risk/Hazard Assessment.

See Risk Assessment "2010 Smoke Transport Research" attached. In addition, a Communications Package, which will include this plan, will be prepared and made available for distribution to Geographic Area Coordination Centers, Regional and State Aviation Officers, Unit Aviation Officers and Incident aviation personnel. The intent is to provide a written briefing to all involved in a wildland fire incident so that when the research aircraft arrives on scene, the incident personnel will be expecting it and understand its role in the fire environment. A contact package is also being prepared that will be carried aboard the aircraft which will contain names and phone numbers of aviation personnel, phone and radio contact information for coordination and dispatch centers, as well as geographic area frequency guides.

The flight crew will contact the Dispatch Center of jurisdiction by phone or radio prior to entering an area where a fire is occurring. The crew will also request the appropriate frequencies (TFR, FTA, and ATGS/ATS) as well as a briefing on participating aircraft, aerial supervision, and any special hazard information. The pilot will check NOTAMs and, whenever possible, the flight crew will attend aviation briefings at the local air bases.

As stated in the 2010 Operations Plan's Project Overview and Mobilization and Deployment Strategy, **although the project does intend to collect samples from the plume, the area of the plume where samples will be collected is downwind from the fire where the smoke becomes less dense as it mixes with ambient air. The particles of smoke collected in this area often may not be visible to the human eye; therefore, this area is commonly not considered part of the plume. The samples will not be taken in the updraft core or in any area which would cause the aircraft to fly in IMC (instrument meteorological conditions).**